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VISUAL SYMPTOMS OF MINERAL DEFICIENCIES OF HEVEA BRASILIENSIS

By

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An account is given of the visual symptoms of Hevea brasiliensis, which appear under deficiency conditions of the macronutrient and micronutrient elements. These symptoms, which are illustrated in colour, were produced in seedlings grown in pot sand culture.

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INTRODUCTION

A description of the effects of mineral deficiencies on the growth and composition of *Hevea brasiliensis* plants grown in one experiment has already been presented (BOLLE-JONES 1954b). However, after several more years investigation of these deficiencies a better and more concise idea of the symptomatology of each deficiency has become available. The following account is a brief description of each deficiency hitherto produced in sand culture; it does not attempt to deal with the rectification of each deficiency under field conditions, an aspect which will be dealt with separately in *Planters' Bulletin*, published by this Institute.

Many of the symptoms, for example those of copper deficiency, have not been observed in the field whereas others, for example those of magnesium deficiency, are of common occurrence. It is possible that replanting with vigorous high yielding clones, exhaustive as it must be of soil mineral resources, may result in the widespread occurrence of various deficiencies. On the other hand, many symptoms may well occur and are not attributed to mineral deficiencies but are loosely described as 'die back', 'rim scorch' and various other descriptive terms because an illustrated description of all mineral deficiency symptoms has not hitherto been available. Similarly, before the artificial production of magnesium deficiency in pot sand culture, many types of interveinal yellowing were ascribed to a lack of magnesium.

Some symptoms, for instance those of magnesium deficiency, are so diagnostic that the deficiency can be confidently recognised without need of confirmation by chemical analysis. Other symptoms, such as those of calcium deficiency, are so ill defined that plant analysis is essential before diagnosis is certain. Still other symptoms, for example those of iron deficiency, may sometimes serve as a more reliable guide to nutrient status than does chemical analysis of the leaves. While a knowledge of the nature of each deficiency symptom can often be used as a means of diagnosis of nutrient status of the tree, this approach is always used in conjunction with the results of analysis of affected and healthy plants in this laboratory for all advisory, or extension, services.

All the investigations which have established the nature of the symptoms described below were carried out on young seedlings, of either clone Tjir 1 or clone PB 86, grown in pot sand culture. As the nature of the symptoms are similar for both clones no attempt is made to differentiate between them in the text or in the legends to the illustrations.

EXPERIMENTAL

Five-gallon clay pots, painted on the inside with bituros paint, were used for the production of the macronutrient element and boron deficiency symptoms; amputated soft glass demijohn jars of similar volume were used for the iron and maganese deficient cultures. Slightly smaller pyrex glass containers, three and a half gallon urn liners, were used to produce copper and zinc deficient plants. All containers possessed a basal drainage hole and contained sifted river sand (particle size 0.5 mm – 1.5 mm).

Sand used for the nitrogen, sulphur, phosphorus, and magnesium deficient cultures was washed with cold weak hydrochloric acid but for the potassium, calcium, iron, maganese, boron, copper, and zinc deficient cultures the sand was washed with hot strong hydrochloric acid solution. Some of the relevant details of the purification procedures have been given, BOLLE-JONES 1954a; others will be published later.

Tap water was supplied to the macronutrient element deficient cultures; distilled water to the iron, manganese, and boron deficient cultures; and rain water, which had been demineralised by passing through ion exchange resin units, was supplied to the copper, and zinc deficient plants.

The composition of the 'complete nutrient' solution which has allowed the most satisfactory growth in our pot sand culture experiments and which was used to produce some of the effects described below was (in milligram equivalents per litre):

NO_3^- 5.0, NH_4^+ 3.0, SO_4^{--} 7.5, PO_4^{---} 3.0, K^+ 3.0, Mg^{++} 2.5, Ca^{++} 4.0, Na^+ 1.0, Fe^{+++} 1.0, Mn^{++} 0.04, BO_3^{---} 0.02, Cu^{++} 0.002, Zn^{++} 0.002, Mo (hexavalent) 0.0012.

The above composition differs from the one formerly quoted (BOLLE-JONES 1954b) and which was used for the earlier part of these investigations.

Tables are given in the *Appendix* to this paper, to show the effect of the various deficiencies on height, girth, leaf production and chemical composition of the leaves. This information chiefly concerns clone PB 86 and supplements that provided previously for clone Tjir 1, but which was obtained with a different nutrient composition (BOLLE-JONES 1954b). These tables may serve as a reference to the effect of each deficiency on growth and chemical composition of the plant.

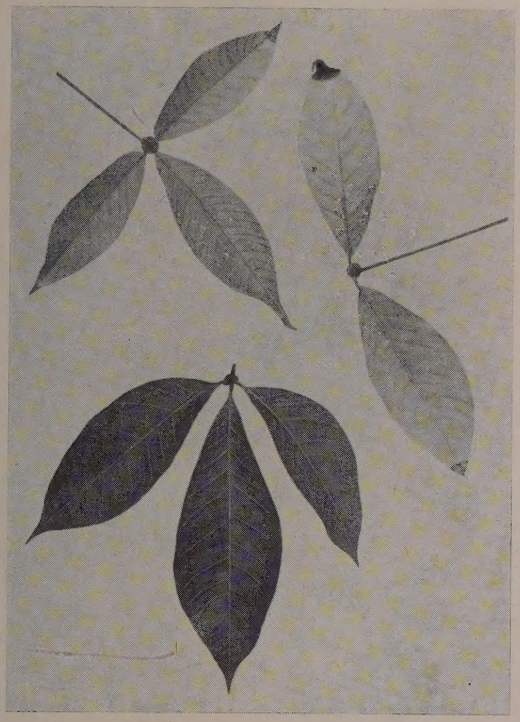
NITROGEN DEFICIENCY

A lack of nitrogen retards growth; the plants become stunted and 'thin'. In the early stages of nitrogen deficiency the plants can be distinguished from healthy plants by the pale yellow or lemon green appearance of the leaves. The size of the leaflet becomes much reduced and paling followed by yellowing sets in. The more severely affected leaflets may develop a tip necrosis which may spread down the lamina.

The symptoms are at first more obvious in the midstem and older leaves which develop a diffuse orange or yellow green mottle as, presumably, the nitrogen is withdrawn from them by the younger leaves. Later, as the deficiency becomes more severe, the youngest leaves may appear yellower and paler than the midstem leaves.

A considerable reduction in the girth of the stem as well as in the number of leaflets produced per storey and per plant occurs as a result of nitrogen deficiency.

Nitrogen deficiency in four months old seedlings: note extreme paleness of upper leaves. Each scale division represents three inches.



Pale nitrogen deficient leaflets (top); healthy leaf (bottom).

Shows stages in severity of nitrogen deficiency in three months old seedlings; note yellowing and indications of necrosis in final stage.

Sulphur deficient plant (left); healthy plant (right). Twentytwo months old seedlings. Note paleness of sulphur deficient leaves.

Stages in severity of sulphur deficiency. Healthy green (left); note general pale green and then sudden change to yellow. Necrosis of tip and margins due mainly to Colletotrichum ficus.

Top of shoot of two years old sulphur deficient seedling. Note marked yellowing and necrosis of laminae.

PHOSPHORUS DEFICIENCY

The rubber tree is very sensitive to a lack of phosphorus. A mild deficiency can cause drastic dimunition in weight, height and girth of the plant together with a reduction in the number of leaflets produced per storey and per plant.

In the early stages growth may appear to be quite vigorous and dark green but later the stems achieve little girth and leaf fall occurs in quite young seedlings. The first visual indication of phosphorus deficiency in young seedlings is the purpling of the underside of some of the laminae in the midstem or uppermost storey, quite apart from the usual type of senescent effect seen in the oldest leaves of the lowest storeys, just before abcission. The upper surface of the expanded laminae may appear as a reddish or faded bronze or olive green, colour; the leaflets are also small. Usually the tip of the lamina becomes scorched and tends to hook inwardly.

In severe instances a tuft of leaves remains near the top of the plant; these may develop marked purple tints and the growing point may finally die.

Phosphorus deficient plants (left); healthy plant (right). Ten months old seedlings.

Lower and upper surfaces of severely phosphorus deficient laminae. Note purplish tinting on undersurface and dull bronzing or reddening of upper surface.

Tops of one year old phosphorus deficient plants. Note lustreless green colour, tip curling, and drooping of laminae.

MAGNESIUM DEFICIENCY

The rubber plant readily produces visual symptoms of magnesium deficiency even though the retardation of growth may be small. The rubber plant is therefore a good indicator of magnesium deficiency. The deficiency, if severe, can cause considerable defoliation and a marked decrease in the total dry weight of the plant.

In rapidly growing young seedlings (two to three months) the first signs of magnesium deficiency may appear as diffuse interveinal yellow areas, near the midrib, which may later become necrotic; these symptoms are usually found in the midstem and lower laminae. In older seedlings (twelve months) the symptoms appear in the older leaves as a yellowing which appears to spread inwardly and interveinally from the margin, giving a herring bone pattern. (However, even where such leaves occur it is still possible to distinguish stages where areas near the midrib appear paler than the marginal region of the lamina.) For a well marked deficiency, the yellow is of bright appearance and the final pattern quite regular; for an incipient or mild deficiency, the pattern is still discernible but the marginal paling is of a dull yellowish green. A scorching of the leaf tip may occasionally occur and, in severe cases, an interveinal necrotic scorch may develop.

Magnesium deficiency symptoms in bottom storeys of seven months old seedlings.

Magnesium deficiency symptoms: (left) second storey leaf from two months old seedling, note slight interveinal necrosis; (middle) typical magnesium deficiency; (right) mild deficiency.

Magnesium deficient leaf.

POTASSIUM DEFICIENCY

A lack of potassium severely limits production of dry matter, girth, height and the number of leaves. The inception of the symptoms of the deficiency is usually sudden and all the foliage may appear noticeably yellower. The symptoms usually appear in the lowest and oldest leaves but, when the deficiency is severe, may spread upwards to the shoot tip.

The symptoms first commence as a mild, diffuse, marginal paleness of the lamina; this pale margin may or may not become mottled or stipled. The marginal border becomes yellower and any mottled areas coalesce. A band of pale green persists, mainly around the midrib, being broadest at the base of the lamina and tapering off towards the leaf tip. The yellow marginal band quickly becomes scorched; scorching may occur all around the lamina margin or may become more localised towards the leaf tip.

The sequence and pattern of the symptoms may appear superficially similar to magnesium deficiency but the laminae do not show a well defined herring bone pattern, and there is usually a marginal scorch present. The pale yellowish green appearance of the whole plant is also a good indication of potassium deficiency in contrast to the more localised nature of magnesium deficiency symptoms. Under conditions of severe potassium deficiency, subsidiary indications of iron deficiency may be noted.

Stages in development of potassium deficiency; the most severe stage, drawn just before abcission, was depicted five days later than the first stage shown.

Potassium deficiency symptoms. Note (left) typical symptoms, marginal yellowing, followed by scorch; (right) symptoms of marginal chlorotic mottling followed by scorch, observed with potassium deficient nutrient in which all nitrogen was supplied as nitrate.

Severe potassium deficiency in five months old seedlings. Symptoms spread to topmost leaves which also showed indications of iron deficiency effects.

CALCIUM DEFICIENCY

Until the inception of the present investigations attempts to produce calcium deficient rubber plants, of smaller dry weight than those supplied with calcium, were unsuccessful (see literature review, BOLLE-JONES 1954b). It is now clear that under well controlled conditions calcium deficiency can seriously limit the growth of the plant (*Appendix*, TABLE I) and even kill it. However, the untapped rubber plant seems to have a very small requirement for calcium and appears to thrive on little of the element.

The symptoms of calcium deficiency are not easy to define. The main effects of the deficiency are observed in the upper parts of the plant. The expanded laminae of the upper storeys develop a ragged margin which is usually extensively necrotically scorched; a preliminary chlorosis or mottling does not precede this necrotic scorch. It appears that sometimes, but not invariably, this scorch may have been caused by attacks of a fungus *Gloeosporium alborubrum*, when the leaves were tender and expanding. Although the same type of scorch may occur in plants amply supplied with calcium it is always true that this scorched or ragged leaf margin is most marked in calcium deficient plants. The laminae appear a dull lustreless green with a papery brown tip or marginal scorch.

Death of the growing point, with consequent dieback, is frequent under conditions of severe calcium deficiency and many new sideshoots may be initiated. These secondary growing points may die, even before the laminae expand, in severe instances of calcium deficiency.

Calcium deficiency effects: (left) necrotic tips of expanded leaves; (right) severely affected leaflets in which some of the effects may be due to fungal attack. Examples from seven months old plants.

Two calcium deficient seedlings (left); healthy seedling (right). Twenty-one months old plants. Note defoliation and dieback in calcium deficient plants. Each scale division represents three inches.

Calcium deficient shoot tip. Same plant shown as middle specimen in photograph (page 533) which was taken eleven days later. Note distortion and ragged margins of leaves and dieback of shoot tip.

Calcium deficient shoot tip. Close up of tip of middle plant shown in the photograph (page 533). Note death of growing points, even those produced low down on stem, before leaf expansion has taken place.

IRON DEFICIENCY

The rubber plant is most sensitive to a deficiency of iron or to any factor such as high pH of the soil which reduces the availability of iron within, or without, the plant. A deficiency of iron greatly reduces the weight of the plant as well as its girth and height; it will also diminish the number of leaves produced.

Iron deficiency is first apparent in the youngest leaves and is usually localised in the upper storeys; sometimes a diffuse mottling or even a chlorosis may occur in the lower leaves when the deficiency is severe. The symptoms originate as an interveinal pale yellow green chlorosis which may later turn to yellow. In severe instances the laminae do not acquire much green colour and become completely yellow or white; this is usually followed by the death of the stem growing point. As the deficiency becomes progressively more severe the shoot tip may become thickened (sometimes referred to as cigar top), the older leaves are abcissed.

Chlorosis due to iron deficiency is usually distinguishable from that caused by other deficiencies as the smaller veins, which connect the larger laterals, remain green; this, for example, is not so for magnesium deficiency.

Iron deficiency effects in shoot tip of three months old seedling. Note chlorotic topmost leaves and older green leaves.

Stages in severity of iron deficiency symptoms. Healthy leaf on left. Note gradual inception of interveinal chlorosis and final production of pale yellowish lamina with green veins.

Severe iron deficiency, seven months old seedling. Note acute chlorosis of apical laminae, defoliation of older leaves and slightly swollen stem tip.

MANGANESE DEFICIENCY

Although the rubber seedling's absolute requirement for manganese is small it readily shows symptoms of the deficiency even if the retardation of growth is but slight.

The symptoms first appear in the midstem leaves and may later spread to the younger leaves as the deficiency becomes more severe. In very young seedlings the laminae become pale green with slightly paler areas between the lateral veins. The veins remain markedly white but are surrounded by green strips of tissue. In older seedlings a similar pattern is observed but the interveinal regions are a much paler yellow green or even yellow, giving a zebra effect.

Under some conditions manganese deficiency may produce a similar pattern to that of iron deficiency but can be distinguished because in iron deficient laminae the identity of the smaller veins is usually distinguishable whereas this is not often so with manganese deficiency.

Manganese deficient shoot tip of eleven months old seedling.

Range of manganese deficiency symptoms. Leaf (left) as observed in very young seedlings—gradual overall paling of lamina. Leaflets (right)—stages typically occurring in older seedlings.

BORON DEFICIENCY

Symptoms of boron deficiency of rubber seedlings have not hitherto been described. One reason for this omission may have been the difficulty in producing this condition in sand culture because of what appears to be a comparatively small requirement for this element. Indeed, under mild deficiency conditions the seedlings may seem to grow better than those supplied with boron. A deficiency of boron will decrease the dry weight of a rubber seedling and slightly reduce its height. At the same time it will increase the number of leaflets borne on the plant.

At first boron deficient plants appear a darker green than those supplied with boron and the leaves are borne in the usual manner, that is, the lower internodes of each flush are longer than the upper so that the leaves appear as separate storeys. Later, when the plant's boron reserves have been depleted, the leaves are no longer produced in discrete storeys but are produced in a regular spiral so that all subsequent internodes are of roughly equal length and storeys cannot be distinguished. The leaves are much smaller and more numerous than usual; this, combined with the absence of storey differentiation, results in the top of the plant assuming a 'bottle brush' appearance. The leaflets do not possess any distinguishable pattern of deficiency but are tough, or stiff, slightly irregular in shape and tend to curl downwardly, towards their ventral surface. Occasionally, but not always, a mild interveinal paling may occur in boron deficient leaves.

When the deficiency is severe the stem growing point dies; numerous side shoots, more than one of which may develop, are given off below the shoot tip.

Healthy plant (left); boron deficient plant (right). Twentytwo months old seedlings. Condition induced by removing all leaves from both and allowing to refoliate. Note many more (and smaller) leaves in boron deficient plant.

Boron deficient plant (left); healthy plant (right). Ten months old seedlings. Note clear differentiation of storeys of leaves of healthy plant and 'bottle brush' effect in boron deficient plant.

Illustration of one year old seedling to indicate transition from discrete storeys of leaves to 'bottle brush' effect. Note smallness of leaves after transition.

Boron deficient leaflets (top), healthy leaf (below). Note: disparity in size; dark green of the boron deficient leaflets.

COPPER DEFICIENCY

A deficiency of copper produces severe and characteristic effects in young seedlings. A marked diminution in dry weight of the plant, in height, and in number of leaves, occurs.

The symptoms first appear near the shoot tips. Leaves are produced which tend to remain pendulous, for longer than usual, and which develop a lime or olive green appearance. The leaves cup inwardly near the tip; this cupped margin turns to a grey wilted appearance. Occasionally the cupping may occur towards the ventral surface of the lamina. The leaflets become progressively paler and the wilted margin changes to a straw coloured or brown scorch which may spread down the lamina, away from the tip. During these changes, the lamina hardens but the scorch grows progressively worse. Finally the lamina is shed at the point where it joins the petiole, to be followed a few days later by the petiole. Frequently a large number of leaves may be shed at about the same time leaving behind a bare stem. The stem growing point usually dies after such a defoliation and necrosis of the stem tip may become extensive. New shoots are then put out lower down the main stem, away from the original growing point, and the sequence of leaf expansion, cupping, scorching and abcission is repeated. In severe instances many of the lower laminae of these new sideshoots will not expand at all and they become withered or atrophied prematurely so that finally a new side shoot may have several stems clothed with numerous dead and shrunken petioles, which appear much like hairs.

The older leaves, produced in the early stages of the deficiency, may develop a pale marginal interveinal mottling followed by a tip and marginal scorch, but these symptoms are by no means as diagnostic as those observed in the younger parts of the plants during the onset of a severe deficiency.

Healthy plant (left); copper deficient plant (right). One year old seedling. Note shoot dieback.

Stages in development of copper deficient leaflets. Note, at first slight inward cupping with grey margin, followed later by appearance of light brown scorch.

Shoot tip of copper deficient plant showing various symptoms of copper deficiency. Note inward cupping of lamina tip, followed by scorch.

Same shoot tip as in above photograph, but ten days later. Note almost complete defoliation and bare stem tips.

Copper deficient seedling, fourteen months old. Note dieback of original shoot tip, production of many new branches which bear hair-like petiole remains, and severe scorching effects in older leaves.

Copper deficient seedling, sixteen months old. Note extensive dieback of stem tips and rotting, proceeding downwards from stem tips. Plant shown was about fortytwo inches tall.

ZINC DEFICIENCY

A deficiency of zinc may markedly reduce the dry weight, girth and height of rubber seedlings. The deficiency is, like that of copper, most destructive when observed in a severe form, and may rapidly kill all terminal growth.

The symptoms are localised in the upper storeys of leaves. The outstanding features of this deficiency are that the laminae become much reduced in breadth, in proportion to their length, and the young leaflets become incurved towards one another and present a hooked or claw appearance, especially in young seedlings. Frequently there is a compression of the apical internodes to give a rosette appearance. The green laminae become 'pronged' by yellowish areas which spread inwardly and interveinally from the margin. The laminae may become twisted and the margins may appear wavy or undulating.

A deficiency of zinc seems to be a predisposing factor to infection by *Oidium heveae* which, in many instances, has been found to envelop the stem growing points of zinc deficient plants. *Oidium* attack may be responsible for some of the distortion observed in expanded zinc deficient laminae and for some of the shedding of young leaves which may occur with a severe deficiency. Under such conditions the laminae may develop a spatulate shape, wavy margins and perhaps become hooked or clawed at the tip, towards the ventral surface of the leaflets; the interveinal regions may be a pale yellow green or yellow, which may later develop brown or orange necrotic patches.

Death of the stem growing points may occur under conditions of zinc deficiency and numerous sideshoots may arise lower down the main stem, or even from ground level.

Healthy plant (left); zinc deficient plant (right). Eleven months old seedlings. Each scale division represents three inches.

Zinc deficiency effects in three months old seedling. Note narrow breadth and hooked or 'clawed' nature of younger leaflets.

Typical zinc deficiency effects in eleven months old seedlings. Note rosette effect, narrow leaflets with well defined interveinal chlorosis.

Zinc deficiency: (left) shoot tip heavily infected with Oidium heveae which surrounds growing point and distorts leaves; (right) zinc deficient leaf not attacked by Oidium—note twisting of lamina of central leaflet.

MOLYBDENUM DEFICIENCY

When rubber seedlings were grown in pot sand culture without molybdenum it was found that the visible effects of the deficiency were very slight, if a large proportion of the nitrogen was supplied in the form of ammonium salts. However, when the nitrogen was mainly given in the form of nitrate salts a marked diminution in growth occurred under conditions of deficient molybdenum supply. Unfortunately the occurrence of iron deficiency, in plants supplied with this nitrate type nutrient, made difficult any interpretation of the observed visual symptoms.

The leaves of the midstem and lower storeys developed a pale brown papery scorch which could be either marginal or towards the tip and cutting transversely across the lamina. These observations need further confirmation before any importance can be attached to the suggestion that they are the direct result of molybdenum deficiency.

DISCUSSION

The descriptions given for the deficiency symptoms are not fully comprehensive as an attempt has been made to distinguish the more diagnostic features which are of greatest help in identification, and to omit symptoms of less specific interest. Symptoms for several of the deficiencies described herein have not previously been published; these include calcium, boron, copper and zinc deficiencies and also some of the symptoms associated with sulphur deficiency. It is noteworthy that most of the micronutrient element deficiencies are well defined and most severe in their ultimate effect. Instances of nitrogen, phosphorus, magnesium, potassium, iron and maganese deficiencies have been noted as occurring in the Federation of Malaya but it is possible that many other deficiencies occur but have not been hitherto recognised.

It was obvious, during the experimental production of various symptoms, that it was much easier to obtain deficiency symptoms for some nutrient elements than for others. In part, this may have been due to defective technique, such as insufficiently pure sand, but it could also have been partially due to a differential requirement for different nutrient elements. If this assumption is correct then it is possible to state that the rubber seedling has a large requirement for nitrogen, but a relatively small one for sulphur and calcium. In addition, even though the absolute requirement may be low, the plant is clearly very sensitive to sub-optimal levels of phosphorus, magnesium, potassium, iron and manganese and will readily show visual symptoms of those deficiencies.

A point of considerable interest which arose from these studies was the association of fungal diseases and nutrient status. Thus infections of *Oidium heveae*, *Gloeosporium alborubrum* and *Colletotrichum ficus* were associated with deficiencies of zinc, calcium, and sulphur, respectively. These observations were incidental to the main objective of the experiments and need to be confirmed by specific experiments to test their validity but they may prove to be valuable clues in the assessment of the occurrence of these pathogens.

The description of the visual symptoms given in the text has been based on experiments with untapped seedling trees. Many of the symptoms (for example, magnesium and potassium deficiencies) which have been observed in the field have been noted in tapped mature trees and are identical with those described above. There is no definite evidence to suggest that

the nature of symptoms described here might alter as a result of tapping.

I acknowledge the assistance, in the care and maintenance of the plants, given by Mr Chin Tet Tsoy and thank Mr Hoh Choo Chuan for his patience and skill in the preparation of the coloured illustrations used in this paper.

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APPENDIX

The relative effect of each mineral deficiency is illustrated in TABLES I, II, III and IV. The composition of the complete nutrient is given on page 496. For the manganese, boron, copper, zinc and molybdenum deficiency treatments none of the restricted element was supplied to the deficient plants but for the other treatments the approximate amount supplied, relative to that of the complete nutrient, is indicated. In many instances, for example magnesium deficiency, TABLE I, the visual effects could be made to appear more drastic by further restricting the supply of the deficient element to the plants; however, the objective was not to kill the plants but rather to keep them in a state wherein they would continue to show leaf symptoms and to provide sufficient foliage for analysis.

It was unfortunate that as a result of an attempt to resuscitate the iron deficient plants with complete nutrient the leaf analysis failed to show the effect of iron deficiency on the iron concentration of the laminae (TABLE II). For this reason an analysis and other data obtained from younger plants, supplied with and without iron, are given as footnotes. Some zinc and molybdenum deficient plants were supplied with a nutrient in which all the nitrogen was given as nitrate; others were given the complete nutrient, referred to previously, which contained ammonium nitrogen in addition to nitrate. When seedlings were supplied with the ammonium nutrient definite symptoms of molybdenum deficiency were not recorded, whereas when given the nitrate nutrient various symptoms were recorded but their interpretation was complicated and made doubtful by the presence of iron deficiency effects.

TABLE I: EFFECTS OF MINERAL DEFICIENCIES ON GROWTH OF CLONE PB 86 RUBBER SEEDLINGS

Plants aged 11½ months; girths taken at 7 cm above sand level; number of leaflets represents average number counted per plant, excluding top storey; the number of storeys which bore counted leaflets, was used to obtain leaflet to storey ratio.

Deficiency	*Proportion of restricted element supplied (in terms of 'complete')*	*Description of deficiency*	*Dry weight of complete plant*	*Girth*	*Height*	*Leaflet number*	*Leaflets/ storeys*
			(gm)	*(cm)*	*(cm)*		
None	*'Complete'*	*None*	516	8.8	244	89	40
Nitrogen	1/6	*Stunted reduced growth, marked symptoms in upper leaves*	133	5.3	152	23	16
Sulphur	1/20	*Slight growth reduction but no definite leaf symptoms*	311	7.4	208	40	27
Phosphorus	1/4	*Severe retardation of growth and symptoms; marked reduction of leaf size and number*	59	4.2	108	*	*
Magnesium	1/6	*Shoots vigorous but marked leaf symptoms; some defoliation*	364	8.1	240	47	32
Potassium	1/20	*Growth reduced, severe symptoms, yellowish appearance*	118	5.3	151	36	23
Calcium	1/20	*Smaller than 'complete' but vigorous. Slight raggedness of young leaves*	293	7.3	184	58	37

Iron	1/100	*Much smaller than 'complete' but no symptoms as plants recently supplied with complete nutrient to prevent death*	123	5.4	144	53	34
Manganese	0	*Vigorous appearance but marked symptoms in upper storeys*	393	8.3	222	85	87
Boron	0	*Slight reduction in growth; obvious bottlebrush effect. Much reduced leaf size but increased leaf number*	305	7.6	191	110	46
		Minimum 5% significant difference	107	1.4	38	26	16
		Minimum 1% significant difference	154	2.0	55	38	24
Footnote							
None	*'Complete'*	*None, plants 6½ months old*	64	—	134	30	12
Iron	1/100	*Severe symptoms of deficiency, plants 6½ months old*	28	—	94	10	4

** All leaflets below top storey position shed; three weeks earlier the leaflet number per plant was 4 and the leaflets to storey ratio was 2.*

TABLE II: CHEMICAL COMPOSITION OF LAMINAE AND RUBBER CONCENTRATION OF PETIOLES OF CLONE PB 86 RUBBER SEEDLINGS GROWN UNDER VARIOUS MINERAL DEFICIENCY CONDITIONS

Plants aged 11½ months; leaves sampled from top and second storey positions. Results presented as % N, S, P, Mg, K, Ca; p.p.m. Fe, Mn, B, of dry lamina; mg chlorophyll per gram of dry lamina: as % rubber in dry petiole.

Deficiency	*Rubber*	*Chlorophyll*	*N*	*S*	*P*	*Mg*	*K*	*Ca*	*Fe*	*Mn*	*B*
None (Complete)	1.0	5.7	3.5	0.28	0.25	0.18	1.3	0.54	84	124	37
Nitrogen	1.3	4.4	2.6	0.20	0.41	0.20	1.8	0.92	62	263	131
Sulphur	1.0	6.5	3.9	0.15	0.34	0.21	1.2	0.72	76	222	44
Phosphorus	—	7.2	3.6	0.22	0.13	0.17	1.2	0.58	80	142	87
Magnesium	1.0	5.4	3.6	0.26	0.26	0.07	1.6	0.88	74	208	30
Potassium	1.2	4.5	3.8	0.22	0.40	0.38	0.4	0.71	78	159	54
Calcium	1.1	6.3	3.8	0.27	0.27	0.30	1.3	0.13	62	140	46
Iron	1.2	6.0	4.0	0.25	0.40	0.24	1.1	0.64	82	90	42
Manganese	1.1	4.9	4.0	0.31	0.32	0.26	1.2	0.62	90	15	45
Boron	1.5	6.3	4.2	0.31	0.38	0.20	1.3	0.84	82	260	3
Min 5% sig. diff.	0.47	1.7	0.69	0.05	0.11	0.07	0.23	0.30	20	51	5.7
Min. 1% sig. diff.	0.69	2.5	0.99	0.08	0.16	0.10	0.33	0.43	29	73	8.2
Footnote											
None (6½ mths old)	1.4	5.3	3.6	0.29	0.32	0.19	1.6	0.88	134	56	37
Iron (6½ mths old)	2.0	4.3	4.0	0.26	0.34	0.30	1.6	0.83	60	130	54

TABLE III: EFFECTS OF COPPER, ZINC AND MOLYBDENUM DEFICIENCIES ON GROWTH OF TJIR 1 RUBBER SEEDLINGS GROWN WITH AN ALL NITRATE NITROGEN NUTRIENT SOLUTION OR WITH THE USUAL SOLUTION, DESCRIBED IN THE TEXT, WHICH CONTAINS NITRATE AND AMMONIUM IONS

Girths taken at 7 cm above sand level; number of leaflets represents average number counted per plant, excluding top storey; the number of storeys, which bore counted leaflets, was used to obtain leaflet to storey ratio.

Deficiency	*Description of deficiency*	*Dry weight of complete plant (gm)*	*Girth (cm)*	*Height (cm)*	*Leaflet number*	*Leaflets/ storeys*
	13 — 14 months old seedlings supplied with NO_3–N and NH_4–N in nutrient					
None	*None*	706	8.9	290	158	43
Copper	*Marked stunting, much branched, severe symptoms, death of some growing points*	110	5.3	122	54	19
	13 months old seedlings supplied with NO_3–N, only, in nutrient					
None	*None*	526	9.6	259	136	39
Zinc	*Reduction in growth, death of few growing points, many sideshoots, Oidium present, mild symptoms*	125	5.4	128	82	12
	13 months old seedlings supplied with NO_3–N and NH_4–N in nutrient					
None	*None*	436	7.8	243	113	38
Zinc	*Growth reduced, Oidium infected shoot tips, very severe symptoms*	46	3.3	86	34	16
	11 months old seedlings supplied with NO_3–N only, in nutrient					
None	*None*	390	7.1	230	60	20
Molybdenum	*Reduction in growth and vigour. Much paler than 'complete', symptoms ill defined*	200	5.6	175	74	19
	11 months old seedlings supplied with NO_3–N and NH_4–N in nutrient					
None	*None*	241	6.1	210	108	32
Molybdenum	*No marked visual symptom of deficiency*	213	5.3	187	95	25

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